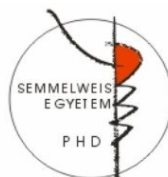


THE ROLE OF PROPRIOCEPTIVE TRAINING IN THE PREVENTION OF LATERAL ANKLE LIGAMENT INJURIES

Ph.D. theses

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Introduction

Injuries to the ankle region represent the most frequent sports injuries, the vast majority (85-90%) affecting the lateral ankle ligaments. In connection with these injuries long-term symptoms or complaints could be detected in 39%. The most important of all consequent pathologies is talocrural instability, which significantly increases the chance to develop long-term complaints and symptoms. Van Mechelen's sequence of prevention for the development of effective prevention methods served as guideline for my dissertation, which intended to prove the preventive effect, but first and foremost the mechanism of this preventive effect of the neuromuscular or neurofacilitation training. This method is often referred to as proprioceptive training, without its proprioceptive effect being ever proven.

According to the first step of the prevention sequence, the population at risk has to be defined, thus sports with the highest frequency of ankle injuries. However, there are no comprehensive literature data available regarding this question. Incidence based on sports-exposure is suitable for comparison of frequencies of ankle injuries in different sports, which expresses incidence in terms of injuries registered during 1000 or 10000 hours of sporting activity.

In the first phase of my studies I performed a meta-analysis based on available literature data (published until January 2002). Hereby I intended to define a ranking of different kinds of sports based on incidence of ankle injuries.

In conformity to the second step of van Mechelen's sequence it can be stated, that the mechanism of the injury and its relation to proprioception is already well described. Based on this, special training drills were developed intending to improve proprioception. While positive effect of this training on balance and peroneus-strength is already proven by many authors in both therapeutic and preventive application, a direct proprioceptive effect could not yet be proven.

To answer the question, whether this special physiotherapeutic method really improves proprioception, I investigated its effect on joint position sense in a group of patients with chronic functional lateral talocrural instability. At the same time, I was looking for evidence indicating its further preventive efficacy.

Following this investigation neuromuscular / neurofacilitative drills were integrated into the regular training regimen of athletes participating in the sport with the highest risk according to the epidemiological meta-analysis. Ankle joint position sense function was measured in these athletes with the same method as in the previously described group before changes in the training regimen were made and 20 months afterwards. By doing so, I intended to prove the proprioceptive mechanism of the preventive effect. Of course I also controlled the preventive effect by means of epidemiological methods, although this way the preventive effect was already proven by other authors.

Aims

1. To define the sports-specific incidence of ankle injuries based on available comparable literature data.
2. To prove the beneficial effect of lower-limb neuromuscular training on the proprioceptive sensory function of the ankle and to investigate the signs of the preventive effect, when applied short-term in a therapeutic fashion.
3. To prove the beneficial effect of lower-limb neuromuscular training on the proprioceptive sensory function of the ankle, when applied long-term in a preventive fashion.
4. To register ankle injury data in connection with the preventive application of the training and evaluating the epidemiological changes.

Methods

Epidemiological analysis of ankle injuries

Based on the database of the Ministry for Youth and Sports, a list of 61 internationally known sports was constructed, for which I searched the MEDLINE database for publications containing ankle injury data. Articles suitable for epidemiological calculations were selected in three rounds. Following the selection process I constructed rankings of different sports based on all three kinds of incidence-rates. The sport, in which I intended to investigate the injury prevention programme and its effects, was chosen based on

the rankings built on exposition-relevant incidence rates. From the same ranking I also conducted statistical calculations to prove, whether the risk of ankle injuries is higher in contact team sports or not.

In order to prove the preventive effect of lower-limb neuromuscular training with epidemiological methods I defined the exposure-based incidence of ankle injuries before and after the introduction of the training. It must be noted however, that my study was in first instance a biomechanical one, thus the dimension of the investigated population could not match the criteria raised to epidemiological studies. Thus, incidence-data of the investigated group of my study can only regarded as an indicator of the preventive effect of the actual training.

Examinations on the proprioceptive sensory function of the ankle

I investigated the effect of neuromuscular training on the sensory proprioceptive function of the ankle on three groups: one control group and two intervention groups (one therapeutic and one preventive). All groups consisted of 10 young elite- and competitive-level athletes with similar baseline characteristics (age, body weight and height, BMI) – with the exception of the all-female prevention group all groups consisting of 5-5 men and women. The first three subjects of the control group repeated the test within 24 hours to prove the reliability of the method.

Therapeutic effect of the neuromuscular training was studied on ten young patients with chronic talocrural instability and healthy contralateral ankles (*therapy group*). After initial measurement of their ankles' proprioceptive sensory function, they performed the neuromuscular training 3x45 minutes per week for 6 weeks. Follow-up measurements were performed at an avg. 7.43 weeks.

I investigated the preventive effect of the neuromuscular training on ten members of a first-class female handball team. They represented the *prevention group* of my studies, where follow-up proprioceptive measurements were performed 20 months after integrating neuromuscular drills into their regular training regimen. Neuromuscular training applied in both the therapy and prevention groups was in its methods identical with those described in international literature.

Proprioceptive sensory function of the ankle was examined with Robbins' "slope-box test". Joint position sense was measured with the help of 11 wooden boxes with different, steadily increasing slope-angles between 0° and 25° in four directions, leading to a total of 44 testing positions on every ankle. Before starting the examination series a random order of test positions were defined. During testing learning effect and visual control related to the boxes were eliminated. The possibility of an overestimation up to 35° was guaranteed.

One subject's above described examination provided for each ankle 44, thus for both ankles a total of 88 estimations (data-points). In

total 4664 data-points (2x1760 from the intervention groups, 880+264 from the control group) were processed. Statistical calculations were made with the help of the Statistica 6.0 software using non-parametric tests based on mean absolute estimate errors.

Results

Epidemiological results of ankle injuries in sports

Regarding all three incidence rates only about 50% of the 119 articles selected in the first selection-round provided ankle- and sports-specific epidemiological data in only about 50% of all sports included in the query. (Table 1)

Of the 119 articles selected in the first round a mere 61 (51.26%) complied with all selection criteria. Based on these I could define exposition-based incidence (IFR) on 30 sports. (Figure 1) Handball (with 2.14 ankle injuries in 1000 sports-exposures) is on the top of this list, followed by five other contact team sports in the top eight positions of the rankings. In these sports ankle- and sports-specific IFR is significantly higher than in other sports ($p=0.0026$).

Table 1

Incidence rate	Sports	Publications
% of all injuries	35 (57.38%)	72 (60.50%)
N / 1000 pers / yr	30 (49.18%)	63 (52.94%)
N / 1000 exp.	30 (49.18%)	61 (51.26%)

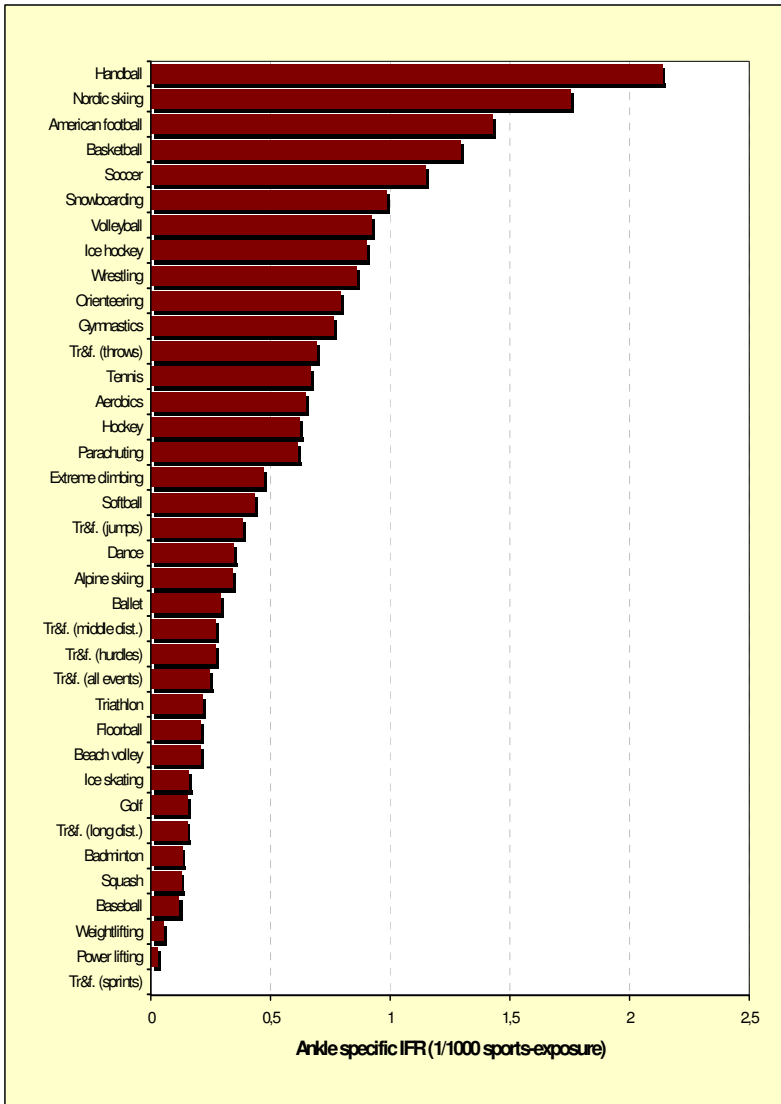


Figure 1
 (Tr&f = track and field, dist. = distance)

Results of the examinations on the proprioceptive sensory function of the ankle

Results of the control group

Characteristics and reliability of Robbins' slope-box test was defined on the results of the control group consisting of ten young healthy athletes. In order to eliminate the distorting effect of the first ascending section of the characteristic curve further analysis was performed in a restricted interval of slope-amplitudes of 7.5°-25°.

In the control group joint position sense of the ankle proved to be independent of side dominance or gender. Test-retest reliability examinations indicated a high split-half reliability in each directions (0.90-0.93), but also combined in all four directions [0.92 (p=0.0013)].

Results of the therapy group

Generally, proprioceptive function of injured and healthy sides improved significantly. Mean absolute estimate errors of the therapy group, which were significantly higher before the start of the training than those of the control group, decreased to the level of controls. Previously existing differences between injured and healthy sides also disappeared. Regarding the magnitude of joint position sense improvement, no significant differences could be detected between different directions.

In comparison to the other three directions, the posterior direction represented an exception for more reasons. While on the injured

ankles in this direction there were no significant differences compared to the healthy sides or to controls at initial measurements, after training injured ankles improved significantly, and showed significantly lower mean absolute estimate errors, than the controls.

Results of the prevention group

The mean absolute estimate error of the prevention group improved strong significantly not only in all directions combined ($p < 0.00001$, Figure 2), but also in every single direction. Regarding the magnitude of joint position sense improvement, no significant differences could be detected between different directions.

While pre-training mean absolute estimate errors were significantly higher compared to controls, they became significantly lower at follow-up. (Figure 2)

Comparing the results of the prevention and therapy groups we can observe, that after training a strongly significant difference became clear in favour of the prevention group. In comparison to the therapy group – both in relation of injured and healthy ankles – decrease of the mean absolute estimate error was also significantly larger in the prevention group.

Regarding side dominance there were no significant differences regarding mean absolute estimate error improvement.

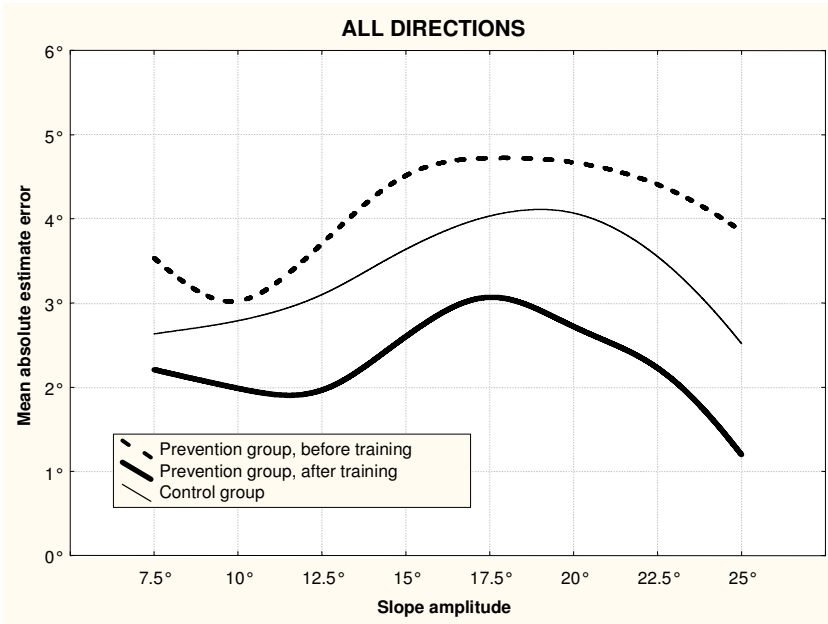


Figure 2

Epidemiological results of the prevention group

Calculated on a team-roster of 15 women the incidence of ankle injuries in the prevention group was *0.88/1000h sports-exposure* before the introduction of the neuromuscular training and *0.34/1000h sports-exposure* at follow-up (-62.1%).

Conclusions

Answers to the formulated questions

1. Regarding the determination of sports-specific incidence of ankle injuries based on available epidemiological data of the international literature I came to the following conclusions:
 - a) Most suitable indicator for the determination of sports-specific incidence of ankle injuries and for the comparison of the registered incidences between different sports is the *sports-exposure based incidence*. This indicates in practice the number of injuries in 1000 or 10000 playing hours. Incidence expressed as percentage of all injuries or number of injuries in 1000 participants per year contain only limited information, and do not provide additional information compared to the exposure-based indicator.
 - b) Of the 119 international publications providing sports- and ankle-specific data available at the time of the query only 51.26% (61 publications) contained sports-exposure based epidemiological data, suitable for comparisons.
 - c) According to the extracted epidemiological data handball has the highest incidence, followed by Nordic skiing and another five contact team sports (American football, basketball, soccer, volleyball, ice hockey) on the next six spots of the rankings.

- d) According to the constructed ranking based on literature data, the risk of ankle injuries is the highest in contact team sports, which can be proved by means of statistics.
 - e) Due to imperfections of currently available literature data a surplus of incidence due to the nature of contact team sports cannot be defined by statistical calculations, but based on the calculated means of incidence it can be estimated at around 0.65 injuries /1000 sports-exposures.
2. Short-term therapeutic effect of lower-limb neuromuscular training on the proprioceptive sensory function of the ankle was investigated on young athletes with chronic talocrural instability. To questions relevant to this dissertation the following answers could be formulated:
- a) Despite recurrent supination injuries, joint position sense of the ankle plantarflexors, first and foremost of the triceps surae muscle, represented by the posterior slopes in the proprioceptive sensory measurements, did not differ in case of the unstable ankles of the therapy group from the results of healthy controls measured in the same slope-direction.
 - b) Neuromuscular training applied on short-term in a therapeutic fashion improved the proprioceptive sensory function of the ankle plantarflexors significantly.
 - c) Post-training joint position sense related to these muscles was significantly better than that observed in healthy controls.

3. Long-term preventive effect of lower-limb neuromuscular training on the proprioceptive sensory function of the ankle was investigated on competitive-level athletes participating in handball, the sport with the highest risk of ankle injuries based on international literature data. Following answers could be formulated to the questions raised:
 - a) Proprioceptive sensory function of the investigated athletes improved considerably. This improvement is significant in every single direction and in all directions combined. Magnitude of the changes is independent of slope directions, thus not indicating differences between muscles groups related in their function to single slope directions.
 - b) No difference could be found between the proprioceptive sensory function improvements of dominant and non-dominant ankles.
 - c) While proprioceptive sensory function of the handball players' ankles was worse before the introduction of the neuromuscular drills when compared to healthy competitive-level athletes as controls, who never received any training or treatment aimed to improve their proprioception, it became clearly better 20 months after changes were made in their regular training regimen.

4. Regarding the epidemiological effects of the training introduced with preventive aims, I was led to the following conclusions:

- a) Although the incidence of ankle injuries in the investigated handball-team decreased considerably by 62.1%, this can only be interpreted as slight indicator of the preventive effect, for this observation was made on a small population, not matching criteria for epidemiological studies.
- b) Pre-intervention incidence-rate and changes in ankle injury incidence of the handball-team representing the prevention group matches injury-rates observed during other, larger epidemiological studies of handball players.

Recommendations

1. I recommend the execution of epidemiological studies – which are of fundamental importance for the development of preventive strategies of sports injuries – following stricter standards, including the expression of incidence based on sports-exposition along with standardised definitions.
2. I proved the positive proprioceptive effect of neuromuscular – a.k.a. neurofacilitation – training in both therapeutic and preventive applications. Based on this I recommend to call the method – just as other authors did previously despite a lack of evidence – *proprioceptive training*.
3. Based on my results, in case of chronic talocrural instability improving after 6 weeks of therapeutic proprioceptive training, I recommend the permanent and regular continuation of the training at a lower intensity (2x30 minutes per week).

4. In order to prevent ankle injuries, I consider the integration of proprioceptive drills into regular training regimens in case of contact team sports – representing the highest injury-risk – indispensable, but I also recommend doing so in other sports.

Summary

Main goal of my study was to prove the positive proprioceptive effect of a preventively applied neuromuscular training in competitive athletes of a high-risk sport – with an epidemiologically already proven preventive effect on ankle ligament injuries.

First, in order to identify the sport with the highest injury-risk, I defined the sports-specific incidence of ankle injuries based on comparable literature data. Processing 119 relevant papers in full-text, published until February 2002, only 61 provided comparable exposition-based, sports- and ankle-specific incidence data. Based on these data, contact team sports feature the highest injury-risk, with handball at the top of the list.

Applying the neuromuscular training in a therapeutic fashion for 6 weeks on young athletes with chronic lateral talocrural instability I observed, that the proprioceptive sensory function of the ankle plantarflexors – represented by the posterior slopes – on the injured side didn't differ significantly from healthy controls before the start of the programme; at follow-up this function improved vastly and became significantly better, compared to controls. This is an indirect sign on the preventive effect of the training.

In accordance with the epidemiological data I examined the proprioceptive sensory effect of preventively applied neuromuscular training on twenty ankles of ten elite-level female handball players. As a result proprioceptive sensory function of the ankle improved in all directions as well as in every single directions strongly

significant, also in comparison to healthy controls. This also justifies the name “proprioceptive training” for this preventive method.

Regarding improvement between single directions, and also between dominant and non-dominant sides, there were no significant differences. In comparison to the therapeutic group it can be stated, that in patients with chronic lateral talocrural instability proprioceptive training should be continued on long-term at a lower intensity after it was successfully applied therapeutically.

While applying proprioceptive drills in a preventive fashion, incidence changes have been similar to those of earlier epidemiological studies, investigating larger samples.

As conclusion I consider the incorporation of proprioceptive drills into the regular training regimen in contact team sports indispensable, in other sports recommended for the prevention of ankle injuries.

List of publications

In conjunction with the thesis

As first author:

1. Kynsburg Á., Halasi T., Tállay A., Berkes I.: Changes in joint position sense after conservatively treated chronic lateral ankle instability. *Knee Surg Sports Traumatol Arthrosc*, 14: 1299-1306; 2006. Epub 2006 Jun 13.

As co-author:

1. Halasi T., Kynsburg Á., Tállay A., Berkes I.: Development of a new activity score for the evaluation of ankle instability. *Am J Sports Med*, 32: 899-908; 2004.
2. Halasi T., Kynsburg Á., Tállay A., Berkes I.: Changes in joint position sense after surgically treated chronic lateral ankle instability. *Br J Sports Med*, 39: 818-824; 2005.

Not in conjunction with the thesis

As first author:

1. Kynsburg Á., Krips R., van Dijk C.N.: Anterior ankle impingement: The role of the dynamic ankle orthosis in the improvement of R.O.M., A pilot study. *Vlaams Tijdschrift voor Sportgeneeskunde en Sportwetenschappen*, 24: 22-28; 2003.
2. Kynsburg Á., van Dijk C.N.: Diagnostic steps for anterior ankle impingement syndrome. *Arthroscopie*, 18: 119-124; 2005.